

NGC 1535 : UV Observations and Models

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Abstract. We reinvestigate the UV spectrum of NGC 1535 by means of recently developed fully line-blanketed non-LTE models. These new models account for the wind in spherical geometry while handling the atomic data in a very similar way to the TLUSTY code. This approach ensures at the same time realistic predictions of the photospheric absorption lines and of the emission lines formed in the wind. Our analysis confirms the results of previous studies. We derive $T_* = 70\text{ kK}$, $\dot{M} = 10^{-7.8} M_\odot/\text{yr}$, and $v_\infty = 2000\text{ km/s}$.

1. Introduction

NGC 1535 is a planetary nebula with a hot central star which belongs to the group of Hydrogen-rich objects with weak winds. The stellar parameters and abundances of these stars can be determined from plane-parallel, static models by fitting their stellar absorption lines (c.f. Werner et al. 2003). A small subset of this group, to which NGC 1535 belongs, shows P-Cygni profiles in the UV which allows for an investigation of their weak stellar winds by means of spherical wind models.

The stellar parameters and the wind properties of NGC 1535 have been well established by Mendéz et al. (MKH, 1992), Perinotto (P, 1993), Tinkler & Lamers (TL, 2002) and Bauer & Husfeld (BH, 1995). In the present paper we confirm these results by applying (for the first time) a new non-LTE code for expanding stellar atmospheres to recently observed HST and FUSE spectra.

2. Observations

We have taken new UV and far-UV spectra of NGC 1535 with HST and FUSE. The HST observation was performed on 2001-03-01 using STIS with the E140M grating, for a total exposure time of 2346 s. It covers the wavelength range 1150–1730 Å at a resolution somewhat higher than 0.1 Å. The FUSE observation with an exposure time of 7862 s was performed on 2003-01-01 with a similar spectral resolution, covering the range 905–1185 Å.

3. Model Calculations

Over the recent years we have analyzed the spectra of several CSPN by applying two non-LTE codes (c.f. Koesterke & Werner 1998). The Tübingen code (Rauch & Werner 1997) was used to fit the photospheric absorption lines while the Potsdam-Kiel code (Koesterke & Hamann 1997) was used to fit the winds lines. The reason behind that was the fact that the Potsdam-Kiel code did not allow for the proper calculation of the quasi-static photosphere. To overcome this unsatisfying situation we decided to write a new non-LTE code which is applied here for the first time. This new code accounts for the stellar wind while handling the atomic data in a very similar way to the widely-used code TLUSTY (Hubeny & Lanz 1995), i.e. incorporating in particular iron line-blanketing and detailed line broadening.

4. Results

We present three models for NGC 1535 which differ in temperature and/or mass-loss rate. The model atmospheres have a solar composition and include H, He, C, N, O, Ne, Si, S, Fe and Ni. A summary of the derived stellar parameters compared to the results of previous studies is given in Table 1.

The relatively strong P-Cygni profiles of the resonance lines of O VI, O V and N V, the weak wind line of C IV and the absorption line of He II (Fig. 1) are well matched by the models. The observed flux is consistent with a reddening of $E_{B-V} = 0.05$.

Table 1. Parameters of NGC 1535

Study ^a	T _* kK	log g (cgs)	M _* M _⊙	log (L _* /L _⊙)	log \dot{M} M _⊙ /yr	v _∞ km/s
MKH	70	4.65	0.65	3.94	-	-
P	77	-	0.55	3.98	-8.85	1900
TL	80.8	5.05	0.605	3.76	-8.7	1900
BH	70	4.6	0.66	4.0	-	-
This study	70	4.6	-	-	-7.8	2000

^asee 2nd paragraph of introduction

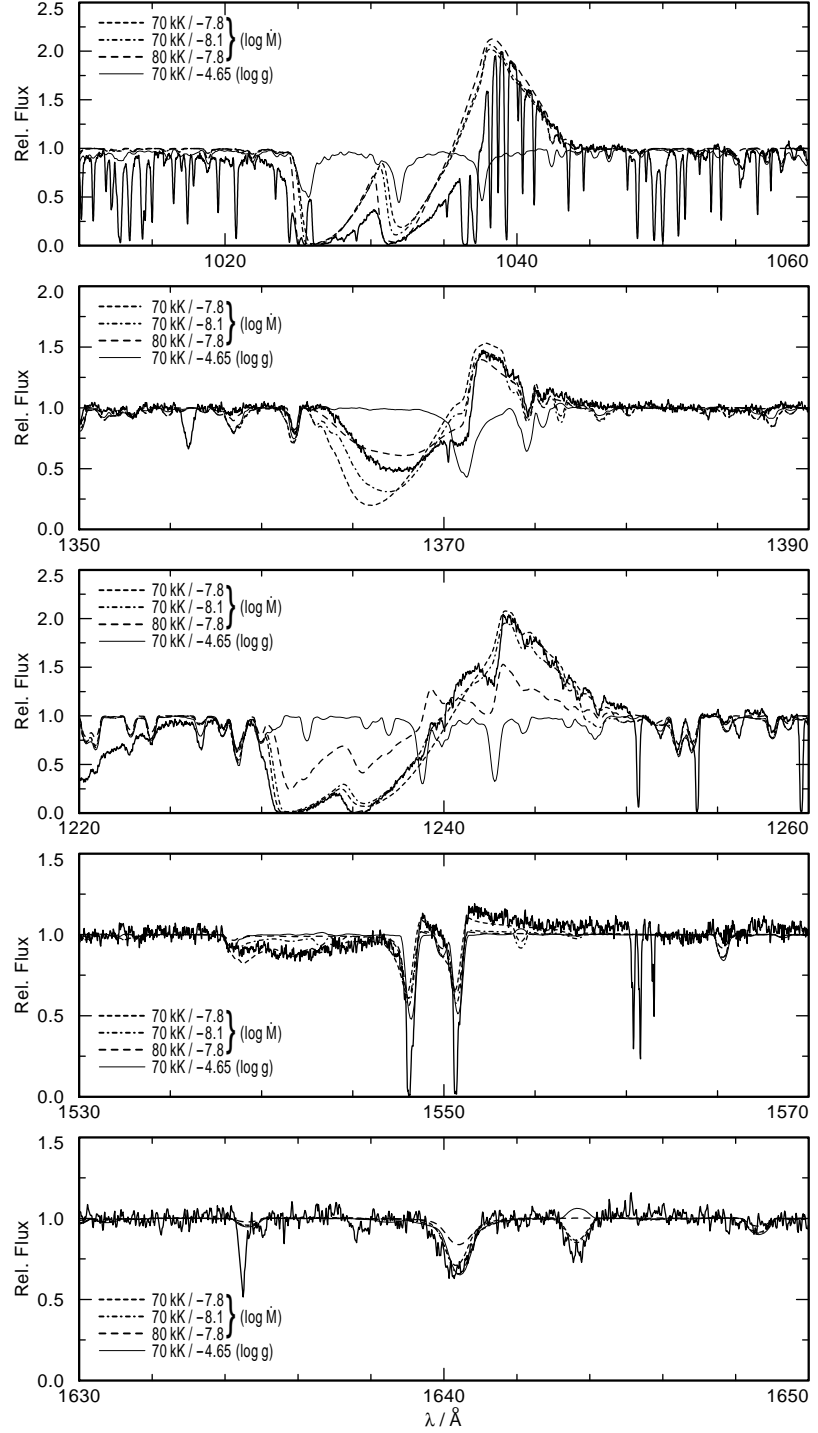


Figure 1. Observation (solid line) of the UV lines compared to the three Wind models (dashed, dash-dotted) and the TLUSTY model (thin solid). A rotation velocity of 75 km/s is adopted.

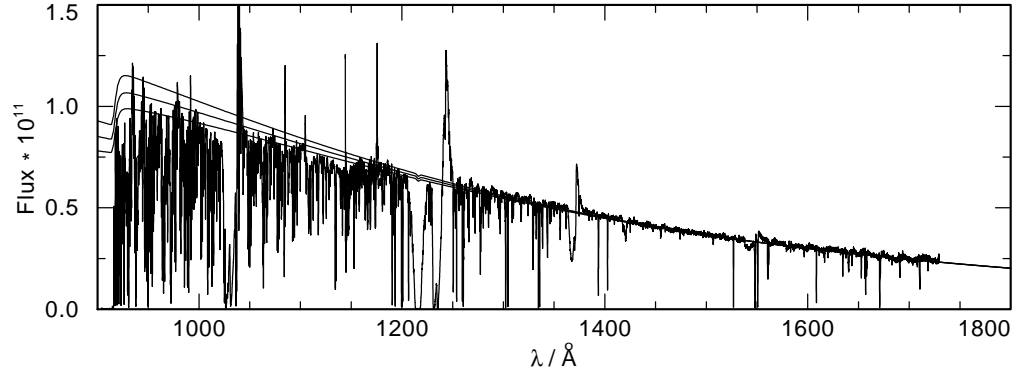


Figure 2. Stellar flux compared to model flux ($T = 70$ kK, $\log \dot{M} = -7.8$ [M_{\odot}/yr]). The model flux is reddened by $E_{B-V} = 0.04, 0.05$ and 0.06 , respectively and normalized to the observation at 1500 \AA .

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